Autonomous Launch, Recovery and Servicing of UUVs from Unmanned Surface Vessels

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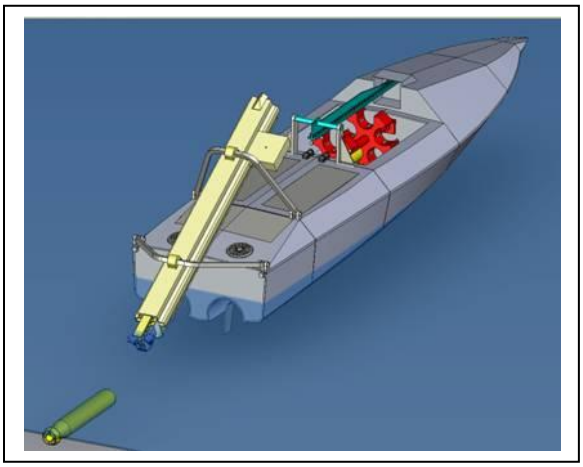

Command: ONR - STTR
Topic: N07-T037

PROBLEM STATEMENT

Unmanned Underwater Vehicles (UUVs) are being used by Naval forces in an expanding variety of roles, including inspection of coastal waters for mines and other hazards. Because the speed and range of UUV missions are limited by UUV propulsion and energy storage systems, UUVs are best transported close to the mission area by manned surface or submarine vessels. However, this approach exposes vessel crews to war hazards and in shallow waters is unavailable to submarines. Utilizing a small and speedy unmanned surface vessel (USV) to deliver, launch, recover and service UUVs is therefore an attractive solution under military development. Hosting UUVs on USVs synergistically combines the range, mission duration, and speed of the USV with the underwater data-gathering capability of the UUV. By hosting several UUVs with differing capabilities, multifaceted missions, such as find-and-kill, can be performed.

The USV must not only be able to launch and recover UUVs, but also be able to download data gathered by them, upload new mission instructions, and recharge or refuel the UUV for further sorties. Significant difficulties lie in the full automation and high reliability required. Small vessels are very susceptible to sea-induced motion, and wave action makes UUVs hard to locate and hard to handle at the surface. In particular, the wave-induced motions of the USV and UUV make lifting the UUV onboard difficult and hazardous to the UUV and boat. To-date, automated L&R of UUVs has been demonstrated only under ideal conditions (calm seas) -- yet mission conditions are seldom ideal.

The UUV, USV and UUV Launch, Recovery and On-board Handling & Servicing System (LROHSS) work together to form a mission module able to operate in elevated sea states. The functions of the LHROSS are complemented by the necessary capability of the UUV to home to, and attach itself to a towfish cable extended from the USV to well below the wave zone. Although underwater surveillance and Mine Counter-Measure

(MCM) missions employing UUVs can be hosted on any number of small surface combatants, the USV-UUV combination requires a host vessel equipped to launch and recover USVs, which at 40 ft in length and about 18,000 lbs in weight, represent a distinct handling challenge. Both versions of the new Littoral Combat Ships (LCS) are specifically equipped for this task and are the primary target for the LROHSS system.

WHO CAN BENEFIT?

The primary contribution of the LROHSS concept is enabling small watercraft to deliver, launch, recover and service several UUVs in remote areas autonomously, reliably, and under adverse conditions. The most important technical advances of the system are in the handling of the UUV as it traverses the water-air interface, and in the supporting methods by which the UUV homes and attaches itself to a submerged hauling cable. These capabilities and technologies may have practical application beyond the LCS MCM mission module.

Although UUVs can provide highly valuable underwater data gathering services, they are normally quite labor-intensive to deploy and service. Most small surface naval vessels operate with very small crews. The LROHSS with cable-homing UUVs would reduce crew debt and enable several types of small manned watercraft to take on underwater surveillance and MCM duties, thereby acting as a widely available force multiplier. By enabling USVs or other small watercraft to host UUVs, more missions can be performed, performed faster, and in more locations, than would otherwise be possible. By performing these missions in a fully automated way from a USV, the risk to human life is decreased. The specific adaptations of the current LROHSS design to the Navy's Mine Warfare (MIW) USV are not critical to the LROHSS function, and might be replaced by a design suited to any number of manned small surface craft. Since UUVs are deployed today from quite large naval vessels as well, the key technical innovations of the LROHSS might be adapted for larger vessel platforms also.

Potential applications for LROHSS-equipped USVs or small manned watercraft could extend beyond Naval applications already mentioned to include harbor inspection, coastal water patrol, or other underwater reconnaissance, search, or surveillance functions performed by the U.S. Coast Guard or Department of Homeland Security. Rescue and relief agencies might also use the capability to survey ports after coastal disasters such as tsunamis and earthquakes or search the seafloor to locate submerged wreckage or hazardous materials. Additionally, the prosperous offshore oilfield services industry is the major user of small submersibles and operates with very high worker safety standards. Automated launch and recovery systems could find commercial application here as well.

BASELINE TECHNOLOGY

At present, UUVs are typically deployed by crane. The UUV is first transported via a cradle trolley from its storage location to a launch and recovery location on the ship. The

UUV is attached at two points to a deck crane, lifted up, swung over the side or stern of the ship, lowered into the water and released. The Lockheed Martin version LCS employs a side-mounted bay and crane mechanism to lower large UUVs and submersibles. The Navy has also developed a chute for lowering a large UUV, the 21-inch diameter BPAUV, on a cable down into the water

Recovering a UUV is considerably more difficult. Typically, the UUV surfaces, yet remains mostly beneath the waves. After it is spotted by the UUV mission team, a small watercraft is deployed to bring divers to the location. The divers manually attach lines and maneuver the UUV close to the host ship for recovery. The lines are transferred to the deck crane and the UUV is pulled up out of the water. Line jerk loads can be significant as the boat and UUV move independently. The UUV may also pendulate significantly once out of the water and must be brought under control before return to its cradle. The Navy chute apparatus noted above must be positioned very carefully relative to the UUV moving in rough water so as to avoid damage to the UUV and the apparatus. Calm seas are highly desirable.

Autonomous L&R to a USV is still in experimental phases. Testing has pre-supposed the UUV already securely attached to a hauling cable, and has been successful only in calm seas. UUV homing and docking technology is also immature. When a UUV reaches a specified location or beacon, it rises to the surface for manual recovery. UUV docking to a fixed underwater “basket” receptacle has been recently demonstrated, but docking and self-attachment to a hauling cable is new and a part of this program’s technology demonstration.

TECHNOLOGY DESCRIPTION

A system concept has been developed that would allow a single USV to deliver, launch, recover, and service multiple UUVs in order to perform a variety of missions without the aid of human crew. The system, referred to as a Launch, Recovery, and Onboard Handling and Servicing System (LROHSS), integrates mechanical, control, and sensor subsystems to task, deploy, service, re-task, and re-deploy multiple UUVs from a single USV. Servicing functions include connecting and disconnecting the UUV from battery charging and data exchange facilities while onboard the USV.

The LROHSS is currently designed to fit over the stern, midsection and mission bay of the Navy’s USV-MIW with modifications only to the cargo hatch. It will accommodate up to six homing-capable UUVs of different sizes in a carousel unit installed in the UUV’s mission bay. The 7.5” diameter REMUS 100 and 12.75” dia. REMUS 600 can be accommodated in the USV-MIW. The LHROSS is capable of handling a 21” dia. BPAUV or other UUV of that size (e.g., the REMUS 1000), but the USV-MIW mission bay is not long enough for it.

The critical innovations of the LROHSS relate to the methods employed to control and position the UUV at the stern of the USV for safe removal from the water while the USV and UUV may be moving energetically in rough seas. Once the UUV is sufficiently

controlled, the mechanism for bringing it aboard utilizes hard points on the UUV skin and avoids dragging, which can damage externally mounted sensors. The system also carries the UUV very low during transit to the mission bay, thereby minimizing stability demands on the USV.

The LROHSS is enabled by new UUV homing and docking technology. This technology permits the UUV to home to a towfish moving a 0-2 knots well below the wave zone. The UUV has the ability to attach itself securely to the towfish cable so that it can be hauled up to the surface and raised partly out of the water to engage the LROHSS operating in and above the wave zone.

Features	Advantages	Benefits
Capable in moderate sea states	• Existing L&R systems require calm seas	• Match sea state rating of USV • Much greater freedom to conduct missions
Removable module for existing Navy USV	• No dedicated USV required	• Mission flexibility for Navy USV assets
Adjusts to wide range of UUV positions during recovery	• Accommodates wide range of USV-UUV relative motion	• Reliable autonomous recoveries • Less risk of damage to UUV or LROHSS
Robotic handling at UUV hard points	• No dragging or sliding that can damage UUV skin, sensors, etc.	• Less risk of damage to UUV or LROHSS mechanism
Carousel in mission bay accommodating up to 6 UUVs	• Multi-UUV missions from single USV	• Faster hazard identification
LROHSS able to handle UUVs of different sizes on same mission	• Hunter-killer UUV suites possible	• Faster hazard clearing
Autonomous servicing of UUVs aboard USV	• Multiple UUV sorties per mission	• Larger areas surveyable • More time to execute complex missions
UUV homing and docking below the wave zone	• No wave interference with docking maneuvers	• More reliable docking
UUV self-attachment to hauling cable	• No need for manual intervention	• Enables autonomous UUV L&R

CURRENT STATE OF DEVELOPMENT

A full-scale prototype launch and recovery mechanism has been designed and built in ATR's laboratory, and fitted to a mock-up MIW-USV topside hull form. Some lab tests of recovery of a REMUS 100 simulant have been performed. ATR's Research Institution partner Woods Hole Oceanographic Institution has successfully conducted in-water tests of the REMUS 100 docking and attaching to a stationary cable with towfish. Docking tests at up to 2 knot speeds are underway. The L&R mechanism and UUV docking are currently at TRL 3-4.

An end-to-end in-water technology demonstration for ONR and the LCS Program Office is programmed for the Option phase the Phase II work. If the Option is awarded, the ATR team will demonstrate in Baltimore Harbor the recovery of a single REMUS 100 by the LROHSS installed on the Navy's High Tow Force USV (USV-HTF) test vessel. The multi-UUV carousel is not essential for this demonstration, and although it has been designed, it will not be built or installed for this testing. Full TRL 4 of the launch and recovery system will be achieved upon a successful demonstration.

In ensuing phases of system development, the servicing and turnaround components of LROHSS would be developed and lab-tested, and the carousel and its mechanism would be constructed. The LROHSS system would be re-installed on the USV-HTF when the system is ready for in-water testing and access to the USV could be scheduled. TRL 5 attainment would then be demonstrated. Testing with the larger REMUS 600 and mixed size REMUS UUVs would occur when a cable-docking REMUS 600 is available for testing. In-water end-to-end testing would be conducted in progressively rougher waters to verify the system's capabilities at higher sea states, thereby achieving TRL 6. Minor design changes for the USV-MIW could then be made in hardware for progressing towards a deployable mission module.

REFERENCES

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ABOUT THE COMPANY

ATR is a well-established engineering-focused Small Business with over 100 employees and over 30 years experience in defense contracting, with emphasis on the US Navy. In addition to its engineering services forte in the analysis, modeling and simulation of weapons effects, the company has two decades of experience in the development and manufacturing of automation systems for military and materials handling applications. ATR is known for its R&D capabilities in the area of real-time control. ATR develops control systems based on the open architecture RCS control methodology, which is ideally suited for complex control and integration problems. Current ATR activities in real-time control and robotic systems development include the control system for the Navy LVI-Lo/Lo crane system, controls for an ONR ship-to-ship ramp system, and UAV launch and recovery programs for DARPA and ONR. ATR has primed automation system manufacturing programs up to the $10 million range for other government customers.